WO0181687

Publication Title:

BUILDING BLOCKS FOR REINFORCED STRUCTURES

Abstract:

Abstract of WO0181687

A method of making a reinforced structure of the type including a body of solidified matrix material, for example a cement based material, and reinforcing elements embedded therein, said method comprising shaping and solidifying matrix material so as to form a plurality of matrix body members (10) which when arranged adjacent to each other form a matrix body with a plurality of elongated cavities (11/12) therein, at least one of the matrix body members having matrix reinforcement components incorporated therein, at least one of the elongated cavities being formed on an interface between matrix body members when arranged adjacent to each other and/or at least two of the elongated cavities being formed transversely to each other and each intersects an interface between matrix body members arranged adjacent to each other, arranging the matrix body members adjacent to each other with reinforcing elements (13, 14, 15) within the said cavities, and interconnecting the matrix body members and the reinforcing elements so as to form said reinforced structure. Reinforced structures made by that method, and a kit of parts for use in that method are also claimed.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
1 November 2001 (01.11.2001)

PCT

(10) International Publication Number
WO 01/81687 A1

(51) International Patent Classification[7]: E04C 3/22, 5/08, E04H 9/10, E01D 19/02

(21) International Application Number: PCT/EP01/04677

(22) International Filing Date: 25 April 2001 (25.04.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

PA 2000 00675	26 April 2000 (26.04.2000)	DK
PCT/IB00/01573	16 June 2000 (16.06.2000)	IB

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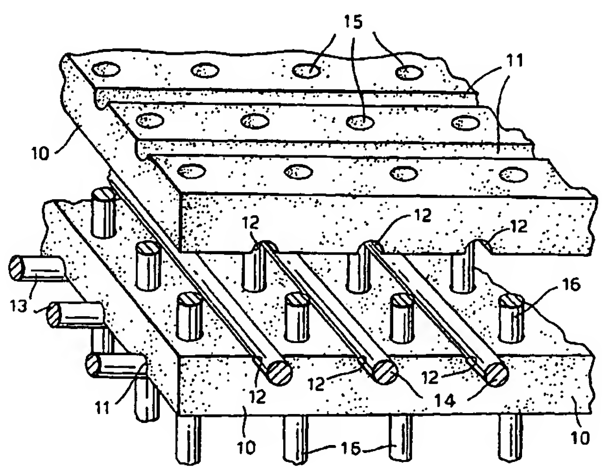
(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

[Continued on next page]

(54) Title: BUILDING BLOCKS FOR REINFORCED STRUCTURES



(57) Abstract: A method of making a reinforced structure of the type including a body of solidified matrix material, for example a cement based material, and reinforcing elements embedded therein, said method comprising shaping and solidifying matrix material so as to form a plurality of matrix body members (10) which when arranged adjacent to each other form a matrix body with a plurality of elongated cavities (11/12) therein, at least one of the matrix body members having matrix reinforcement components incorporated therein, at least one of the elongated cavities being formed on an interface between matrix body members when arranged adjacent to each other and/or at least two of the elongated cavities being formed transversely to each other and each intersects an interface between matrix body members arranged adjacent to each other, arranging the matrix body members adjacent to each other with reinforcing elements (13, 14, 15) within the said cavities, and interconnecting the matrix body members and the reinforcing elements so as to form said reinforced structure. Reinforced structures made by that method, and a kit of parts for use in that method are also claimed.

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Building Blocks for Reinforced Structures

The present invention relates to a method of making a reinforced structure of solidified matrix material with reinforcing elements embedded therein, to reinforced structures made by that method, and to a kit of parts for use in that method..

Solidified matrix materials include cement based materials such as cement paste, mortar or concrete; ceramic materials; plastics materials; metals and metal alloys; and any of the foregoing when they are "composite materials", that is materials which consist of a system of components, often including fibre reinforcement. Examples of interesting composite materials are reinforced, e.g., fibre-reinforced, so-called DSP materials disclosed e.g. in US Patents Nos. 5,234,754 and 4,588,443; US Patent No. 4,588,443 gives a definition of DSP materials, and illustrates a number of such materials when cement-based. Common to all of these solidified matrix materials is that they are normally made by solidification of a shapeable, e.g. mouldable, phase such as a liquid or plastic phase.

One method of making such structures is the classical method of providing a mould or cavity in which the main reinforcing elements, e.g., rods, threads or cables, such as, e.g., 5-25 mm diameter strong bars or cables of steel, are positioned in the desired arrangement, and subsequently filling liquid or plastic matrix material into this mould or cavity where the matrix material is allowed to solidify so that the reinforcing elements are embedded therein. Efficient methods, useful for casting structures of this type with complex internal structure, using mechanical vibration, are disclosed in US Patent No. 4,979,992. This patent discloses how fibre-reinforced DSP materials as matrix materials may be combined with extremely high volumes of main reinforcement to result in structures – so-called CRC structures - of extreme strength, stiffness and toughness; an important further development of these structures are the structures disclosed in WO 98/30769 in which extreme impact resistance has been obtained by tension interlocking of the main reinforcement system.

The present invention provides a new method by means of which such reinforced structures may be made in a more flexible manner, allowing production of reinforced structures with characteristics which to a great extent may be selected and designed to fulfil predetermined criteria. The method makes it possible to obtain reinforced composite structures of typically much better quality and with better performance by establishing more rational structures on both macro and micro level.

The present invention provides a method of making a reinforced structure of the type including a body of solidified matrix material and a plurality of reinforcing elements embedded therein, said method comprising

shaping and solidifying matrix material so as to form a plurality of matrix body members which when arranged adjacent to each other form a matrix body with a plurality of elongated cavities therein,

at least one of the matrix body members having matrix reinforcement components incorporated therein,

at least one of the elongated cavities being formed on an interface between matrix body members when arranged adjacent to each other
and/or
at least two of the elongated cavities being formed transversely to each other and each intersects an interface between matrix body members arranged adjacent to each other

arranging the matrix body members adjacent to each other with reinforcing elements within the said cavities, and

interconnecting the matrix body members and the reinforcing elements so as to form said reinforced structure.

The time period over which the above method is implemented is immaterial to the invention. For example, the matrix body members may be shaped and solidified immediately prior to arranging the reinforcing elements in the cavities and subsequently carrying out the interconnection step. However, it will often be preferred to shape and solidify the matrix body members far in advance of their use in the remaining reinforcing element insertion and interconnection steps. The latter method of implementation suggests that another aspect of the invention is a kit of parts comprising preformed solidified matrix body members, reinforcement elements shaped for insertion into the cavities formed by the arranged matrix body members, and interconnecting means for interconnecting the matrix body members and the reinforcing element or elements so as to form a reinforced structure.

It will be noted that the eventual reinforced structure produced by the method of the invention comprises a plurality of discrete matrix body members arranged adjacent one another like building bricks.. The interconnection of the reinforcing elements and the body members confers structural integrity on the assembly of body members, thereby producing the desired reinforced structure. It is possible to include, in the final structure, domains which are made by conventional casting around the main reinforcement, and/or domains consisting of a material which is not a solidified matrix material, e.g., natural rock. However, it is preferred that the matrix body members constitute at least 50% by volume of the matrix part of the final reinforced structure, more preferably at least 80% by volume, and still more preferably at least 90% by volume, such as at least 95% by volume, it being normally most preferred that all or substantially all of the matrix part of the final reinforced structure is constituted by the matrix body members and the binder binding them together.

Since reinforcing elements are to be arranged in the cavities in or defined by the arranged matrix body members, either the cavities must be accessible to receive the reinforcing elements from the exterior of the matrix body formed by arrangement of the discrete matrix body members, or the matrix body must be assembled with the reinforcing elements in place by arranging the discrete matrix body members in their positions with the reinforcing members pre-positioned to occupy the cavities formed as the matrix body members are thus arranged.

In the method of the present invention the matrix body members may be shaped, e.g. cast or moulded, separately from the reinforcing elements. However, an interesting alternative that may be used for all or part of the matrix body members of a final reinforced structure is that the individual matrix body member may be shaped from a shapeable matrix body in contact with the reinforcement with which it is later to be in intimate contact, the shapeable body thereby being given its final shape or substantially its final shape. The thus shaped matrix body member may then be allowed to solidify, either as the final matrix body or as a "green" body which is then subjected to its final shape- and strength-conferring solidification, such a by a high temperature sintering, at least this final shape- and strength-conferring treatment being performed with the matrix body separated from the reinforcement. In cases where the solidification, e.g. high temperature sintering, results in shrinkage of the matrix body member, this can be compensated for, e.g. by using a model of the reinforcement and other environment with which the final solidified matrix body

member is to fit, the model being larger than the real environment by a factor corresponding to the shrinkage.

The matrix body members and the reinforcing elements may be bound together by suitable interconnecting means so as to form a unitary reinforced structure. By choosing among a great variety of interconnecting means, including mechanical means, binders and adhesives, it is possible to obtain a desired mechanical behaviour of the reinforced structure when exposed to an excessive load, such as a controlled mutual sliding of the matrix material in relation to the reinforcing elements with controlled energy absorption.

The method according to the invention allows high flexibility in making reinforced structures. Thus, a desired number of matrix body members may be used for forming the matrix body which means that the actual size or dimensions of the reinforced structure to be produced does not necessarily dictate the method and equipment to be used for shaping the matrix body members forming the matrix body. Thus, the matrix material may be vibrated, compressed or otherwise compacted by means of the most efficient equipment available, exposed or heated to a desired temperature, surface finished, exposed to electrical or magnetic fields, and/or to radiation to, e.g. effect hardening of a binder, e.g. polymerisation of a monomer, such as radioactive radiation.

Because the size of the matrix body members may to a high degree be selected according to the intended final use of the resulting structure, the matrix body or matrix body members may be machined or subjected to another mechanical treatment subsequent to shaping and solidification thereof.

The reinforcing elements may be interconnected to the matrix body or body members by any suitable means, such as mechanical means, e.g., bolting, riveting, binding or tying or welding, or complementary, mutually engageable shapes, etc. If it is desired to make the final structure detachable, bolting or tying, optionally combined with complementary, mutually engageable shapes may be the preferred interconnecting means. In many cases, however, the interconnection will be obtained by means of one or more binders which are able to bind to adjacent surfaces of the matrix bodies and/or to adjacent surfaces of the reinforcing elements and the matrix body or matrix body elements, respectively. The binder or binders used may be any glue, adhesive or other binding agent. The binder or binders, which may be a one, two or a multi-

component binder, may be introduced or injected into the spaces or cavities of the matrix body in a paste-like or liquid form, when the reinforcing elements have been arranged therein, and subsequently allowed to solidify within the spaces or cavities. The binders may, e.g., be plastics-based binders such as thermoplastic binders or chemically hardening plastics binders, glass type binders, such as soldering glass, which solidify from a melt, particle-based materials, such as cement paste, which solidify by precipitation, nucleation and growth, metals which solidify from a melt, e.g. low-melting metal or alloys such as soldering brazing, and ceramic slurries which solidify by sintering; all of the binders may contain reinforcing components, such as particles and/or fibres.

Alternatively, or as a supplementary measure, a binder or binder component may be applied to the outer surface of the reinforcing elements prior to arranging the reinforcing elements in the cavities. Alternatively or additionally the binder or a binder component may be applied to the inner surfaces of the matrix body or body members defining the spaces or cavities prior to arranging the reinforcing elements within these spaces or cavities. When a two-component or multi-component binder is used at least one further gaseous or liquid binder component may subsequently be introduced into the spaces or cavities of the matrix body so as to activate the binder composed by said components, and/or the binder system may be activated by irradiation, including radioactive irradiation.

Adjacent surface parts of matrix body members may be shaped so as to mechanically interlock said matrix body members. Alternatively adjacent surfaces of matrix body members may be bonded together by an intermediate layer of adhesive material, including cement based adhesive material.

The surface parts of the reinforcing elements on one hand and adjacent surface parts of the matrix body or matrix body members on the other hand may be shaped so as to mechanically interlock the reinforcing elements and the matrix body or body members. As an example, the interlocking surfaces may form a dove tail connection or have any other complementary shapes preventing mutual movement of the interlocked parts in at least one direction.

It will be understood that the above-mentioned interconnecting techniques may be combined with each other in any suitable way adapted to the particular purpose.

The combination of the matrix body or matrix body members and the reinforcement may be adapted to the particular use of the final structure. Thus, the matrix and the reinforcement may be interconnected in such a manner that they have a controlled interaction with each other with respect to the desired properties dictated by the end use. It is a particular advantage of the present invention that the interconnection between the reinforcement and the matrix can be made to have any desired firmness, varying from a rather loose interconnection allowing a controlled sliding greater than a sliding in a structure made by conventional casting around a reinforcement to a very firm interconnection with a positive compressive force between the matrix and the reinforcement permitting less sliding than in a structure made by conventional casting. In both cases, it may be possible to obtain an interaction between matrix and reinforcement which is better controlled than in structures made by conventional casting.

At least one of the matrix body members has matrix reinforcement components incorporated therein. However, It is normally preferred that all or substantially all of the matrix body members are reinforced in this way. Thus, when the matrix body members are made, any type of reinforcing component may be included therein and may form a secondary group or subgroup of reinforcements or subordinate reinforcements in the final reinforced structure being formed. Such reinforcing components may comprise fibres, wires, rods, strands, net-like structures, sheets, and/or plates. Very interesting structure systems that may be implemented in the individual matrix bodies or matrix body members are the so-called CRC structures disclosed, e.g., in US. Patent No. 4,979,992. It should be understood that while the subordinate reinforcement components are embedded in the matrix body members when moulding the same, the "main" reinforcing elements of the final structure are separate from the matrix body and the matrix body members until the matrix body or matrix body members have been finally solidified and are assembled with the separate "main" reinforcing elements to form the reinforced structure.

As an important example, the matrix material may a fibre reinforced material. Alternatively or additionally, composite matrix bodies or body members may be formed by stacking two or more flat, solidified matrix body members with intermediate layers of a binder material, which may or may not be different from any of the binders used for interconnecting the matrix body members and the reinforcing elements. Said binders and/or binding material may contain reinforcing fibres or other reinforcing means.

Usually it is desirable to form the matrix body members from a material which is compact and strong. However, in some cases it may be desirable that the solidified matrix material is a porous material, and a suitable binder may then be injected into the pores of the porous material. Thereby this material may be made compact and strengthened, and preferably at the same time the matrix body members and/or the matrix body members and the reinforcing elements may be mutually interconnected.

Matrix body members forming the matrix body of the reinforced structure made by the method according to the invention may be made from the same type of matrix material. However, in some cases the matrix material may advantageously comprise two or more different materials, i.e. at least first and second different materials having different characteristics. The matrix body members forming a single matrix body may then be made from such different materials. The various matrix body members made from two or more different matrix materials may then be mutually arranged in the matrix body so as to impart desired strength or other characteristics to the final reinforced structure.

The reinforced structure made by the method of the present invention may be of any kind, whether large or small. The structures may be final application structures such as a machine part, or a much larger building structure. They may also be construction elements for an ultimate final application structure, such as a bridge, bridge pier, a building, a military defence structure, or the like.

Depending on the kind of structure to be made, the matrix material may be selected from a group of suitable materials, such as cement-based materials, ceramics-based materials, metal- or metal alloy-based materials, plastics materials, glass, or any other mouldable and solidifiable material. As mentioned above, the materials may suitably be of the type advanced particle-based composites such as DSP materials. The terms "mouldable material" and "solidifiable materials" and the starting materials from which the "solidified materials" are made should be understood to comprise any liquid or plastic material which may harden or solidify, and any powdered or particulate material which is mouldable and solidifiable, for example by compression and/or heating and/or sintering so as to provide a unitary, coherent body. The powdered or particulate material may include a binder which may be activated by compression, radiation and/or heating or in any other manner. In the method according to the invention the size or dimensions of the matrix body members may

be chosen such that the moulding process is as efficient as possible by using the processing equipment available. As mentioned above, the so-called CRC structures are interesting structures of the matrix materials

Some kinds of matrix materials, such as ceramic materials, are solidified at very high temperatures, which would destroy or deteriorate the material of many otherwise available reinforcing elements. Therefore, the conventional method of embedding e.g. metal reinforcing elements therein cannot be used. By using the method according to the invention in which the matrix body elements are made separately, e.g. with ceramic reinforcement, and subsequently combined with the metallic reinforcing elements this problem is solved.

The cavities for receiving the reinforcement elements will normally be shaped in a complementary fashion to the shape of the reinforcing elements. Thus, in one preferred embodiment, the cavities are in the form of linear bores for receiving reinforcement in the form of rods.

In general, however, the reinforcing elements used in connection with the method of the present invention may be of any suitable type which may be arranged within the cavities defined in the matrix body. Thus, the reinforcing elements may be in the form of rods, wires, strands, plates, sheets, and/or profile members, and such reinforcing elements may be made from any suitable material conventionally used for such purpose, such as metals, metal alloys, glass, plastics material and carbon.

The present invention further provides a reinforced structure comprising

a plurality of shaped solid matrix body members arranged adjacent to each other form a matrix body with a plurality of elongated cavities therein,

at least one of the matrix body members having matrix reinforcement components incorporated therein,

at least one of the elongated cavities being formed on an interface between matrix body members

and/or

at least two of the elongated cavities being formed transversely to each other and are formed so that each intersects an interface between matrix body members

reinforcing elements being arranged within the said cavities, and

the matrix body members and the reinforcing elements being interconnected by binding material having a composition different from that of the matrix body members to which they are interconnected. The binder or binders may be selected so as to provide good bonds between opposite surfaces of the matrix body members on one hand and between the matrix body or matrix body members and the reinforcing elements on the other hand. Furthermore, the binder or binders may be chosen so as to impart desired strength characteristics to the reinforced structure.

Aspects of the invention will now be further described with reference to the drawings, wherein

Fig. 1 is a perspective view of part of an embodiment of a reinforced structure according to the invention,

Fig. 2 is a plan view and partly sectional view of a matrix member forming part of the structure shown in Fig. 1,

Fig. 3 shows different types of reinforcing elements, which may be used in connection with the present invention,

Fig. 4 and 5 illustrates a reinforcing element surrounded by a plurality of matrix body members,

Fig. 6 illustrates a reinforcing element surrounded by two layers of matrix body members,

Figs. 7-9 illustrate various embodiments of the structure according to the invention in which structures of the type shown in Figs. 3-5 are incorporated,

Fig. 10 is a cross-sectional view of a further embodiment of the structure according to the invention

Fig. 11 is a perspective view of another embodiment of the structure according to the invention,

Fig. 12 illustrates a structure comprising matrix body members with mutually engaging complementary surfaces and wire-shaped reinforcing members,

Fig. 13 illustrates a method of making a matrix body member,

Figs.16-19 illustrate the shaping of matrix body members suitable for use in the invention from mouldable precursor members, prior to solidification of the matrix body members.

Fig. 1 shows a first embodiment of a reinforced structure according to the invention. The structure comprises a plurality of fibre-reinforced matrix body members 10, of which two are shown, having parallel grooves or channels 11 and 12 formed in opposite side surfaces thereof. The grooves or channels 11 and 12 extend transversely and preferably at right angles to each other. The two matrix body members 10 are shown arranged with faces having grooves or channels12 opposite each other. In general, the plurality of body members 10 are arranged such that opposed faces of adjacent members are those having corresponding grooves or channels In this way, aligned channels 11 and 12 formed on the interface of abutting side surfaces of adjacent body members define elongated cavities, in the form of bores or passages, for receiving main reinforcing elements 13 and 14.

An array of bores 15 is formed in the body members 10 extending substantially at right angles to the side surfaces of the body members. When the matrix body members are arranged as described in the preceding paragraph, these bores are aligned and define additional elongated cavities in the form of bores or passages to receive further reinforcing elements 16.

The body members 10 are made separately from a mouldable matrix material, for example from fibre-containing concrete, another cement based material, or from a fibre-containing DSP material which may be cement-based, plastics-based or metal-based, by moulding or casting. Because the size of each body member 10 is small compared to the size of the structure made thereby, the matrix material being shaped may be efficiently compacted by compression and/or vibration in a known manner. With respect to reinforcement, the matrix material from which the body members are made may be fibre reinforced as mentioned above. Alternatively or additionally a net-like reinforcement 17 or similar matrix reinforcing component(s) may be embedded in the matrix body members 10 during moulding thereof, as shown in Fig. 2.

The reinforcing elements 13, 14 and 16 shown in Figs. 1 and 2 are rod-shaped metal elements having a substantially circular cross-section. Depending on the size and desired properties of the final reinforced structure, the size of the reinforcing elements may vary over a broad range, from very thin threads over rods of diameter in the "normal" range of 5-25 mm to larger diameters. According to a special aspect of the invention, the reinforcing elements may be large with diameter, e.g., 60-100 mm, or very large, with diameter, e.g., 600-1000 mm, the large or very large reinforcing elements preferably being in the form of cables or other composite

structures. However, as illustrated in Fig. 3 the cross-sectional shape of the reinforcing elements may be different. Thus, Fig. 3a - d show square, rectangular, angular, and meander-shaped cross-sectional shapes, respectively. . Figs. 3e and 3f illustrate reinforcing elements formed by fibres or wires in a round and a flat cross-sectional arrangement, respectively. Preferably, the cross-sections of the elongated cavities receiving the reinforcing elements correspond to the cross-sectional shapes of the reinforcing elements

The matrix body members 10 and reinforcing elements 13, 14 and 16 forming the structure illustrated in Fig. 1 are interconnected by a suitable binder, which may be applied to adjacent surfaces of the structure components when building up the reinforced structure, or the binder in liquid form may be injected into the spaces defined between adjacent body members 10 and between body members 10 and adjacent reinforcing elements 13, 14 and 16 subsequent to assembling the matrix body members and the reinforcing elements.

Fig. 4a shows a reinforcing element 18 in the form of a bundle of wires twisted together. Reinforcing elements of this type may be used in a reinforced structure as shown in Fig. 1. However, each such reinforcing element 18 may be enclosed within a plurality of solidified lining members 19. Fig. 4b illustrates a pair of such lining members 19, which together defines a through-going bore 20 for receiving the reinforcing element 18 therein. The lining members 19 may be interconnected and bound to the reinforcing element 18 by means of one or more binders. Lined reinforcing elements of the type shown in Fig. 4c may replace the reinforcing elements 13,14, and 16 in a structure of the type shown in Fig. 1. The matrix body members 10 and the lining members 19 may be made from different matrix materials having different strength characteristics. Therefore, by combining suitable different matrix materials a reinforced structure according to the invention having desired strength and mechanical behaviour characteristics may be obtained.

Fig. 5 illustrates a method for producing a lined reinforcing element functionally similar to the lined reinforcing element shown in Fig. 4c. The lined reinforcing member shown in Fig. 5a comprises a rod-shaped reinforcing element 18 surrounded by a plurality of annular lining members 19 threaded thereon. The reinforcing element 18 is preferably made from steel or another metal and the lining members 18 may, for example be made from ceramics or a similar material. As illustrated in Fig. 5b the annular or ring shaped lining members 18 may be formed from a particulate starting

material 21 in a compression mould 22 comprising a cylinder and a pair of opposed pistons or plungers 23 and 24. One piston 23 has a central projection or stud 25, which may engage with a corresponding blind bore 26 in the other piston 24. In the mould the particulate material may be compressed so as to form a "green" sample. The green samples 27 may be heated in a furnace or oven to a sintering temperature, such as about 1400 degrees centigrade - indicated at 28 - so as to form the annular lining members 19. Finally, the lining members 19 may be threaded on the rod-shaped reinforcing element 18 as illustrated in Fig. 5c and bound together and to the rod 18 by means of a suitable binder. Lined reinforcing elements thus produced may be used for making a more complex structure of the type shown in Fig. 1.

Fig. 6 illustrates an example of a rod-shaped reinforcing element 18, which is provided with a double lining. Thus, the lining comprises an inner lining formed by a number of annular, cylindrical lining members 19 similar to those shown in Fig. 5, and an outer lining formed by a number of outer lining members 29. Each of outer lining members 29 has a shape similar to the shape of the lining members 19 shown in Fig. 4. A space 30 is defined between the inner and outer lining and a binding material for interconnecting the lining members 19 and 29 is arranged within this space. This means that each reinforcing element 18 is surrounded by three layers of material, which may have different strength characteristic. The reinforcing element 18 with the surrounding lining members 19 and 29 may be incorporated in a complex structure as shown in Fig. 1. The characteristics of the various lining materials may be chosen such that a certain load to which the structure is exposed causes a desired mutual movement of the reinforcing element 18 and the surrounding lining and matrix materials so as to allow the reinforced structure to receive and convert a high amount of energy, such as impact energy. Consequently, by using the method according to the invention it is possible to tailor a reinforced structure so that it is able not only to carry a predetermined working load, but also to show a desired mechanical behaviour in case the structure should become exposed to unexpected excessive loads.

Fig. 7 illustrates a building structure member, which comprises fibre-reinforced matrix body members 10 made from ceramics, cement based materials and/or DSP materials. These body members 10 define through-going passages 31 with a rectangular cross-sectional shape for receiving lined reinforcing elements 18,19 of the type illustrated in Fig. 4c. As shown in Figs. 8 and 9, the outer surfaces of the

lining members 19 and the complementary inner surfaces of the matrix body members 10 defining the passages 31 may be shaped so as to obtain a mechanical interlocking between the lining members 19 and the adjacent matrix body members 10 against mutual movement in the longitudinal direction of the reinforcing elements 18. In addition, the various elements forming the reinforced structure may be bound together by one or more suitable binders being introduced in the spaces defined between the elements or parts forming the structure. As shown in Fig. 9 a plurality of aligned bores 15, which extend transversely to the reinforcing elements 18 may be formed in the matrix body members 10 for receiving further rod-shaped reinforcing elements, which are made for example from steel.

Fig. 10 illustrates a building structure member constituted by a plurality of plate-like matrix body members 32, which are arranged in layers. Each plate 32 may be made from a cement-based matrix, e.g. a cement-based DSP matrix material, around secondary matrix reinforcement components 33 in a conventional manner. As shown in Fig. 10 such matrix reinforcement components may comprise a plurality of parallel rod members interconnected by transverse wires passed around the rod members and having a substantially sinusoidal shape. A primary reinforcement is formed by a plurality of substantially parallel, rod shaped reinforcing elements 34, which are arranged between the layers of matrix body members 32 in channels or grooves formed in the outer surfaces of the plate-like members 32. Also the primary reinforcement comprises sinusoidal reinforcing wires 35 extending in planes substantially at right angles to the rod-shaped elements 34 for interconnecting the same. The primary reinforcement may further comprise rod-shaped reinforcing elements 36 extending substantially at right angles to the elements 34 and arranged between layers of the plates 32 where no reinforcing elements 33 are arranged. Also in this case reinforcing elements extending transversely to the layers of plate-like matrix body members 32 may be arranged in aligned bores (not shown). The various members and elements of the structure may be bound together by one or more different binders.

The structure illustrated in Fig. 11 comprises superposed layers of elongated panel- or plate-like matrix body members 10. Each body member 10 has longitudinally extending grooves or channels 11 and 12 formed in one of its side surfaces for receiving rod-shaped transversely orientated reinforcing elements 13 and 14. Each layer of the structure is formed by pairs of the plates or panels 10 with reinforcing elements 13 or 14 sandwiched there between and received in bores defined by

oppositely arranged channels 11 or 12. As shown in Fig. 11 the elongated panels or plates 10 may extend substantially at right angles in alternating layers of the structure. Furthermore, the plates or panels have bores 15 formed therein being aligned with bores in adjacent panels, whereby passages or bores are defined in the structure for receiving reinforcing elements 16 which extend transversely to the layers of the structure. The plates or panels 10 may be formed from a compressed or compacted cement or DSP-based material or a ceramic material containing conventional matrix reinforcement components, such as fibres of plastic, glass, carbon and/or metal and/or metallic rods and/or wires. Furthermore, the members and elements of the structure may be bound together by one or more binding agents.

Fig. 12 illustrates how a pair of adjacent matrix body members 10 forming part of a structure in accordance with the present invention may have complementary stepped shapes for mechanically interlocking such members against mutual movement in two directions at right angles. The body members 10 have aligned bores 37 therein extending in said directions for receiving cables or wires 38 or other reinforcing elements which are preferably tensioned so as to maintain the matrix body members in close mutual contact.

In Fig. 13 it is illustrated how matrix body members 10 of the type shown in Figs. 1 and 11 may be made. A matrix body member 10 may be made from a particulate starting material 21, which may contain reinforcing fibres, in a compression mould 22 comprising a cylinder and a pair of opposed pistons or plungers 23 and 24. One piston 23 has ridges 39 for forming the channels or grooves 11 in the member 10 to be produced. The transverse openings or bores 15 may be formed by means of pin-shaped plungers 40, which are moveable in relation to the other mould parts. In the mould the particulate material 21 may be compressed so as to form a "green" sample 27 which may be allowed to cure or harden. Alternatively, the green sample 27 thus made may be heated in a furnace or oven to a sintering temperature as previously described.

In the embodiments described above, the method of the invention has been illustrated by the use of preformed solidified matrix body members. However it may be preferred that the matrix body members – or some of them – are in fluid/plastic condition during their mutual arrangement and arrangement relative to the

reinforcement elements, with final solidification taking place before interconnection of the matrix body elements and the reinforcement elements. In this aspect of the method of the invention, the said matrix body members may

1) be wholly or partially enclosed in a flexible/thin enclosing/delimiting body and/or
2) have an internal stability and only to a small extent or not at all be enclosed in thin enclosing/delimiting bodies.

The method may be performed by arranging the said matrix body members in said fluid/plastic condition, with or without the said flexible enclosing/delimiting/enveloping bodies, adjacent to neighbouring matrix body members and reinforcement elements and, by mechanical influence bringing them in intimate contact with the said adjacent matrix body members and reinforcement elements.

Thus, Fig. 16A shows the placing of a matrix body member **1** in plastic fluid condition, wholly or partially surrounded by or enclosed in a flexible intermediate body, or without such intermediate body, prior to placing in intimate contact with a matrix body member **3** and an intermediate reinforcement element **4**. By mechanical influence, the matrix body member **1** is given its final shape in intimate contact with **3** and **4** against which it is shaped. The situation illustrated in Fig. 16A is the situation before this mechanical influence. The matrix body member **1** is shown placed loosely on **3** and **4**. Corresponding matrix body members in corresponding positions are indicated **1-a**, **1-b**. Above the matrix body member **1**, a press tool **5** is shown in a position on its way to be pressed down against the matrix body member **1**.

Fig. 16B shows the situation after the matrix body member **1** has been pressed, by means of the press tool **5**, into intimate contact with the matrix body member **3** and the reinforcement element **4** and has, thereby, been given its "final" shape **2**, in contact with the matrix body member **3** and the reinforcement element **4**, and together with the neighbouring deformable matrix body member **1-a** and **1-b** which at the same time have been given their "final" shape **2-a**, **2-b**.

The underlying matrix body member **3** and reinforcement **4** may be stiff, and relatively non-yielding. Alternatively, both, or one of them, may be plastic/fluid, wholly or partially, or not at all enveloped in a flexible intermediate body.

A flexible intermediate body, e.g., in the form of a thin membrane, net or web, serves in particular to keep fluid/plastic sub-bodies together while they are being placed, analogously to how a water-filled bag can be placed on a floor, with a brick on top of

it, in intimate contact with the floor and the brick and with controlled geometry (constant surface area) without flowing out.

Figs. 17 and18 show variants of the situation illustrated in Fig. 16.

Fig. 17 illustrates the introduction of an intermediate body **6**. In Fig. 17, a two part press tool consists of the intermediate shaping body **6** and a supporting body **7**.

Fig. 17A shows the position with the shaping body **6** and the supporting body **7** on their way to be pressed down against the matrix body member **1**. Fig.17B shows the situation after the compression, with the shaping body **6** in intimate contact with the now deformed matrix body member **2**.

Fig. 18 illustrates that the matrix body members has a composite structure, illustrated by matrix reinforcing components **10** and **11**. The system is as in Fig. 17 with a deformable matrix body member which is designated **8** prior to the deformation process and **9** after the deformation process. The matrix body member contains the component **10** in contact with another component **11**, e.g. fibres. **12** designates a body against which **8** is pressed, with a reinforcement element **13** between them. The matrix reinforcement components **10** and **11** differ from each other with respect to their capability of being deformed. During shaping, the embedding component **11** is in plastic/fluid condition. The embedding component **10** may be stiff, substantially non-yielding, but it may alternatively be in plastic/fluid condition.

By operating with matrix body members in fluid/plastic condition, with controlled/controllable shape, a number of advantages are obtained compared to the classical method of casting of the whole matrix body; these are largely the same as are obtained using the building brick principle with solid matrix body members, including the feature that the matrix body members in fluid/plastic condition can contain components, such as reinforcement components, which are prearranged in a desired configuration and will substantially retain their configuration during shaping. However, compared to the building brick principle according to the present invention implemented with solid matrix body members, a far better/much easier intimate contact can be obtained between matrix body members and between matrix body members and reinforcement elements.

Fig. 19 shows a section of a reinforced structure during its production. **1** is a solid matrix body member with reinforcement elements **2** completely embedded therein and vertical reinforcement elements **3** embedded and protruding from the upper surface of the matrix body member **1**. In grooves on the upper surface of the matrix body member **1**, horizontal reinforcement components **4** are placed, with about the upper half of them extending above the upper surface of the matrix body member **1**. Another matrix body member **5**, in plastic/fluid condition, wholly or partially – or not at all – enveloped by/enclosed in a flexible thin delimitation body, is shown immediately before it is mechanically brought into intimate contact with the matrix body member **1** and the reinforcement elements **4**. A contour **6** indicates the shape of the matrix body member **5** after it has been brought into intimate mechanical contact with the matrix body member **1** and the reinforcement elements **4**.

The invention provides many possibilities of combinations. Thus, e.g., the matrix body member **1** may be of ultra-strong, hard, fracture-tough ceramic material produced by high pressure/high temperature sintering. The reinforcement elements **2**, **3** and **4** may be cables/rods of ultra-strong steel, or another very strong material, and the sub-body **5** may be fluid metal containing reinforcement, e.g. ceramic fibres, or fluid metal matrix-based composite enclosed in a bag woven of ceramic fibres.

The above-illustrated principle of the invention, using flexible "building blocks" of a solidifiable material may be used for other purposes than for embedding/surrounding a reinforcement. Thus, e.g., a "building block" of a solidifiable material may be used as an interlocking member formed *in situ* by being compressed into a cavity of such a shape that the building brick, when solidified, will interact with surrounding structural components to lock the structure. A solidifiable "building block" which solidifies in situ may, e.g., be constituted by a cement-based DSP material. Such a component may be pre-mixed, optionally packed in a flexible packing material and pre-shaped to a suitable slab shape and then cooled or frozen, which will stop or retard the cement hardening process, for later warming/heating or thawing at the site of use, thereby establishing the ready-to use self-solidifying "building block".

As previously mentioned, the conventional method of making reinforced structures has involved casting matrix material in a fluid state into the voids of a pre-arranged array of reinforcing elements, then hardening the cast mass in contact with the reinforcement. The casting is often preferably combined with mechanical vibration and/or applied external stresses, such as pressure and shear stresses and/or applied

forces of inertia such as by impact or centrifugation. Preferably, the processes are aided by high frequency mechanical vibration applied to the reinforcement. Subsequently the matrix material solidifies, through solidification processes related to the matrix materials in question, such as solidification of melts, sintering, polymerisation, nucleation and precipitation. Compared with this conventional method, the method of the present invention permits:

1. Rational design and construction of

1.1 normally-sized, large and very large structures with closely arranged reinforcement which may be large, and

1.2 extremely strong, hard, stiff, fracture-tough structures, both large and very large and with extremely closely arranged reinforcement,

1.3 where the space between the reinforcement elements is filled with dense matrix material with a complex internal structure, comprising, e.g., cubically shaped bodies with sizes of the same order of size as the transverse dimensions of the reinforcement, and with rods, fibres, etc. in high concentrations incorporated in a sub-matrix.

2. production of structures of higher quality made possible through

2.1 better combinations of selection of materials and mechanical production (compression, vibration etc.)

2.2 better combinations of selection of materials, mechanical production processes and subsequent solidification processes; thus, e.g., the solidification of the matrix body members may take place over large temperature ranges and large pressure ranges

2.3 production of complex structures, such as composite structures with hard, strong, fracture-tough matrices, and strong reinforcement elements which can be present in high concentration relative to the size of the matrix body elements

2.4 building in of “tailor-made” combinations of various matrix body members, for example having special shapes allowing effective interlocking, having shapes

conferring friction interlocking (interaction conferred by friction forces in structures where two bodies which otherwise have a tendency to slide relative to each other under separation from each other have the sliding and separation tendency counteracted by friction forces aided by compressive forces on the sliding surfaces, the compressive forces increasing as the bodies are moved away from each other, this being obtained, e.g. by using wedge or dovetail geometry), having various functions, such as, e.g., containing electrical conductors, cooling channels, heating channels, channels for introduction of "glue" or fluid matrix material for joining the matrix body members, etc., and building in of "tailor-made" interface structures, and

2.5 industrial mass production, combining mass production of matrix body members and automatic assembling of the these and appertaining reinforcement elements.

The preparation of the structure according to the invention may partially be performed by casting the matrix material in fluid plastic condition around the reinforcement, with subsequent solidification of the matrix material, but with the added freedom that at least a part of the matrix material which fills the void between the reinforcement components is prepared separately from the reinforcement, the process then being characterized by

1) preparation of the matrix body members separately from the reinforcement components,
2) subsequent placing of at least some of the matrix bodies and reinforcement in the final position or substantially the final position, and

subsequent mutual fixation of the parts of the matrix body and fixation of the matrix body to the reinforcement.

As will be understood from the above discussion, the invention permits production of reinforced structures not obtainable by the conventional method because according to the invention, the production of the individual matrix body member may be adapted to the particular structure of the member and the particular type of materials of the member. Thus, e.g., the individual matrix body members may be produced according to the suitable methods for obtaining structures of high or very high strength, stiffness and toughness, e.g. the methods disclosed in the above-mentioned patents and further developments thereof. This means that the invention is particularly important in connection with establishment of reinforced structures from matrix body members

having certain properties reflecting high quality, the final reinforced structures thereby obtaining corresponding high quality. In the following, a discussion of a number of these properties is given.

Thus, in a preferred embodiment, the invention provides a shaped article comprising a reinforced domain (A) comprising a matrix body (B) and a reinforcement (C) embedded in said matrix body (B), the reinforced domain (A) having a high stiffness in any direction and/or a high resistance to compression in any direction, as defined by

1. the modulus of elasticity related to the reinforced domain A and/or the matrix body B in any direction being at least 30 GPa, and/or
2. the resistance to compression of the domain A and/or the matrix body B in any direction being at least 30 MPa,

the volume of the reinforcement C being at least 2% relative to the volume of the reinforced domain A, and

the tensile strength of the reinforcement being at least 200 MPa.

The above-mentioned preferred minimum modulus of elasticity and resistance to compression (compressive strength) also apply the solidified matrix body members.

More preferred embodiments are where the modulus of elasticity, expressed in GPa, of the solidified matrix body members, or of the reinforced structure, is at least 40,
or at least 50,
or at least 60,
or at least 80,
or at least 100,
or at least 150,
or at least 250,
or at least 300,
or above 300,
important intervals being 60-150 and 150-300.

Preferred are also embodiments where the resistance to compression (compressive strength), expressed in MPa, of the solidified matrix body members, or of the

reinforced structure, for any direction (arbitrary orientation in a rectangular coordinate system x-y-x in relation to the body in question) is at least 40.
or at least 60,
or at least 120,
or at least 180,
or at least 250,
or at least 400,
or at least 600,
or at least 1000,
or at least 1500,
or at least 2500,
or at least 4000,
important intervals being 60-120, 120-250, 250-600, and 600-1500 MPa.
MPa.

Preferred are also embodiments in which the tensile strength, expressed in MPa, of the reinforcing elements – which are elongated bodies such as rods or plates having the capability of absorbing high influences in tension in the length direction for rods , and in at least one direction in the plane for plates – is at least 250,
or at least 300,
or at least 400,
or at least 600,
or at least 800,
or at least 1000,
or at least 1200,
or at least 1500,
or at least 2000,
or at least 2500,
or at least 3000,
important intervals being 300-1000 and 1000-3000 MPa.
The tensile strength, expressed in MPa, of the solidified matrix body members, or of the reinforced structure may be in one of the intervals
10-30,
30-100,
100-300, or even in one of the above-mentioned intervals.

Preferred are also embodiments in which the volume of reinforcement arranged in the cavititis is such that the volume of reinforcement elements, excluding any lining thereof, in the reinforced structure, defined as the sum of the percentage ratio between reinforcement area and total area in three mutuallhy perpendicular sections of the reinforced structure is at least 2%
or at least 3%,
or at least 5%,
or at least 8%,
or at least 10%,
or at least 12%,
or at least 15%,
important intervals here being 3-5%. 5-10% and 10-15%,
or at least 20%, at least 30% or at least 50%, or more than 50%. However, in certain cases, the volume of the main reinforcement may be as low as 1%.

The volume of reinforcement in the matrix body members may be the same as stated above for the volume of main reinforcement in the final structure.

The volume proportion of particles/bodies in the matrix body member may be vary over a wide range, e.g. as represented by the intervals
10-30%,
30-50%,
50-60%,
60-70%,
70-80%,
80-90%, or
larger than 90%

The number of reinforcing components in one direction in the final structure is preferably at least 2, more preferably at least
or at least 3,
or at least 4,
or at least 6,
or at least 8,
or at least 12,
and preferably at least 2

in a direction perpendicular thereto
and more preferably at least 4,
and preferably at least 2 in the third possible perpendicular direction.

Preferred are also embodiments in which the fracture energy, expressed in kN/m, of the solidified matrix body members, or of the reinforced structure, is in one of the following intervals:
2-5,
5-20,
20-50,
50-200,
200-1000, or
larger than 1000,

or where the parameter $\frac{G}{H}$ constituted by fracture energy G divided by size (thickness) H, expressed in N/m^2, of the solidified matrix body members, or of the reinforced structure, is in one of the following intervals:
10^4-$3*10^4$
$3*10^4$-10^5
10^5-$3*10^5$
$3*10^5$-10^6
10^6-$3*10^6$
$3*10^6$-10^7
10^7-$3*10^7$
$3*10^7$-10^8
10^8-$3*10^8$
$3*10^8$-10^9,
or larger than 10^9,

in x direction, preferably in all directions in the x-y plane, and preferably in all directions.

The number of matrix body members in a final structure may, e.g. be in one of the following intervals:

2-5,

5-20,

20-100, or more.

the size (thickness) of the individual matrix body members may vary over a wide range, depending, inter alia, on the size and character of the final structure. Thus, for very small systems, it may be in one of the following intervals:

1-10 μm

10-100 μm,

100-1000 μm,

1-10 mm,

10-100 mm,

100-1000 mm,

1 m – 10 m, or, in special cases, larger than 10 m.

At least to some extent adapted hereto, the size (thickness, diameter) of the main reinforcement may be in one of the following ranges:

0.1-1 μm

1-10 μm

10-100 μm,

100-1000 μm,

1-10 mm,

10-100 mm,

100-1000 mm,

or, in special cases, larger than 1 m.

The size (thickness, diameter) of the reinforcement of the matrix body members may be in one of the following ranges:

0.01-0.1 μm

1-10 μm

10-100 μm,

100-1000 μm,

1-10 mm,

10-100 mm,

or above 100 mm.

The size of particles/bodies in the material constituting the matrix body members may be in one of the following ranges:

0.01-0.1 μm

1-10 μm

10-100 μm,

100-1000 μm,

1-10 mm,

10-100 mm,

or above 100 mm.

Claims:

1. A method of making a reinforced structure of the type including a body of solidified matrix material and a plurality of reinforcing elements embedded therein, said method comprising

shaping and solidifying matrix material so as to form a plurality of matrix body members which when arranged adjacent to each other form a matrix body with a plurality of elongated cavities therein,

at least one of the matrix body members having matrix reinforcement components incorporated therein,

at least one of the elongated cavities being formed on an interface between matrix body members when arranged adjacent to each other
and/or
at least two of the elongated cavities being formed transversely to each other and each intersects an interface between matrix body members arranged adjacent to each other

arranging the matrix body members adjacent to each other with reinforcing elements within the said cavities, and

interconnecting the matrix body members and the reinforcing elements so as to form said reinforced structure.

2. A method according to claim 1, wherein at least one of the elongated cavities is formed on an interface between matrix body members arranged adjacent to each other.

3. A method according to claim 2, wherein at least one additional elongated cavity is formed which intersects the said interface.

4. A method according to any of the preceding claims, wherein the elongated cavities are in the form of essentially linear bores.

5. A method according to any of the preceding claims, wherein at least one of the reinforcing elements is a lined reinforcing element.

6. A method according to any of the preceding claims, wherein substantially all of the plurality of matrix body members have matrix reinforcement components incorporated therein.

7. A method according to any of the preceding claims, wherein at least one of the matrix body members is in a fluid/plastic condition and is arranged adjacent to one or more other matrix body members and one or more reinforcing elements and is brought in intimate contact with the said other matrix body member(s) and one or more pre-arranged reinforcing elements by mechanical influence, the one more reinforcing elements thereby forming an elongated cavity on an interface between the fluid/plastic matrix body member and the said other matrix body member(s), and then the fluid/plastic matrix body member(s) is/are solidified and interconnected with the other matrix body member(s) and the reinforcing element(s) so as to form the reinforced structure.

8. A method according to claim 7, wherein the matrix body member or members which is/are in a fluid/plastic condition contain(s) matrix reinforcement components which substantially retain their configuration and orientation under the mechanical influence.

9. A method according to any of the preceding claims, wherein the modulus of elasticity of the solidified matrix body members, or of the reinforced structure, is at least 30 GPa.

10. A method according to claim 9, wherein the modulus of elasticity of the solidified matrix body members, or of the reinforced structure, is in the interval 60-150 GPa.

11. A method according to claim 9, wherein the modulus of elasticity of the solidified matrix body members, or of the reinforced structure, is in the interval 150-300 GPa, or above 300 GPa.

12. A method according to any of the preceding claims, wherein the compressive strength of the solidified matrix body members, or of the reinforced structure, is at least 30 MPa.

13. A method according to claim 12, wherein the compressive strength of the solidified matrix body members, or of the reinforced structure, is in the interval 60-120 MPa.

14. A method according to claim 12, wherein the compressive strength of the solidified matrix body members, or of the reinforced structure, is in the interval 120-250 MPa.

15. A method according to claim 12, wherein the compressive strength of the solidified matrix body members, or of the reinforced structure, is in the interval 250-600 MPa.

16. A method according to claim 12, wherein the compressive strength of the solidified matrix body members, or of the reinforced structure, is in the interval 600-1500 MPa.

17. A method according to claim 12, wherein the compressive strength of the solidified matrix body members is in the interval 1500-4000 MPa, or above 4000 MPa.

18. A method according to any of the preceding claims, wherein the tensile strength of the reinforcing elements is at least 300 MPa.

19. A method according to claim 18, wherein the tensile strength of the reinforcing elements is in the interval 300-1000 MPa.

20. A method according to claim 18, wherein the tensile strength of the reinforcing elements is in the interval 1000-3000 MPa, or larger than 3000 MPa.

21. A method according to any of the preceding claims, wherein the volume of reinforcement elements arranged in the cavities is such that the volume of reinforcement elements, excluding any lining thereof, in the reinforced structure, defined as the sum of the percentage ratio between reinforcement area and total

area in three mutually perpendicular sections of the reinforced structure is at least 2%.

22. A method according to claim 21, wherein the volume of the reinforcement is in the interval 3-15%.

23. A method according to claim 22, wherein the volume of the reinforcement is in the interval 3-5%.

24. A method according to claim 22, wherein the volume of the reinforcement is in the interval 5-10%.

25. A method according to claim 22, wherein the volume of the reinforcement is in the interval 10-15%.

26. A method according to claim 21, wherein the volume of the reinforcement is at least 15%.

27. A method according to any of the preceding claims, wherein the number of reinforcing elements arranged in cavities extending in one direction is at least 3.

28. A method according to claim 27, wherein the number of reinforcing elements arranged in cavities extending in one direction is at least 6.

29. A method according to claim 27, wherein the number of reinforcing elements arranged in cavities extending in one direction is at least 12.

30. A method according to claim any of claims 27-29, wherein the number of reinforcing elements arranged in cavities extending in a direction perpendicular to the said one direction is at least 4.

31. A method according to claim 30, wherein the number of reinforcing elements arranged in cavities extending in the third possible perpendicular direction is at least 2.

32. A method according to any of the preceding claims, wherein the reinforcing elements are rod-shaped and have a diameter of at least 60 mm.

33. A method according to claim 32, wherein the reinforcing elements have diameters in the interval between 60 mm and 100 mm, and/or between 100 mm and 250 mm, and/or between 250 mm and 600 mm and/or between 600 mm and 1200 mm and/or between 1200 mm and 3000 mm.

34. A method according to any of the preceding claims, wherein the fracture energy of the solidified matrix body members, expressed in kN/m, is in one of the following intervals:

2-5
5-20,
20-50
50-200
200-1000
or larger than 1000.

35. A method according to any of the preceding claims, wherein the matrix material is compacted or compressed when shaped into a matrix body or matrix body members.

36. A method according to any of the preceding claims, wherein the matrix body members are machined or subjected to another mechanical treatment subsequent to shaping and solidification thereof.

37. A method according to any of the preceding claims, wherein the reinforcing elements are interconnected with the matrix body or body members by mechanical means and/or by means of one or more binders.

38. A method according to claim 37, wherein binder is introduced or injected into the cavities of the matrix body in a liquid form, when the reinforcing elements have been arranged therein, and subsequently allowed to solidify within the cavities.

39. A method according to any of claims 1-37, wherein a binder or binder component is applied to the outer surface of the reinforcing elements prior to arranging the reinforcing elements in the cavities.

40. A method according to any of the claims 1-37, wherein a binder or binder component is applied to the inner surfaces of the matrix body members defining the cavities prior to arranging the reinforcing elements within these cavities, or subsequently to arranging the reinforcing elements within these cavities.

41. A method according to any of claims 1-38, wherein at least one further gaseous or liquid binder component is subsequently introduced into the spaces or cavities of the matrix body so as to activate the binder composed by said components.

42. A method according to any of the preceding claims, wherein the matrix body members are shaped so as to mechanically interlock with adjacent matrix body members.

43. A method according to any of the preceding claims, wherein surface parts of the reinforcing elements on one hand and adjacent surface parts of the matrix body members on the other hand are shaped so as to mechanically interlock the reinforcing elements and the matrix body or body members.

44. A method according to any of the preceding claims, wherein the matrix body reinforcement components are ore include fibres.

45. A method according to any of the preceding claims, wherein the matrix body members are composite material body members.

46. A method according to any of the preceding claims, wherein the solidified matrix material is a porous material, a binder being injected into said porous material so as to mutually interconnect the matrix body members and/or to connect the matrix body members with the reinforcing elements.

47. A method according to any of the preceding claims, wherein the matrix material comprises at least first and second different materials having different characteristics, matrix body members being made from such different materials.

48. A method according to any of the preceding claims, wherein said reinforced structure is a building structure or an element of a building structure.

49. A method according to any of the preceding claims, wherein the matrix material comprises a material selected from the group consisting of cement based materials, ceramics based materials, plastics materials, metal or metal alloy materials, including DSP materials, and glass.

50. A kit of parts for constructing a reinforced structure, comprising preformed solidified matrix body members as defined in any of the preceding claims, reinforcement elements shaped for insertion into the cavities formed by the arranged matrix body members, and interconnecting means for interconnecting the matrix body members and the reinforcing element or elements so as to form a reinforced structure.

51. A reinforced structure comprising

a plurality of shaped solid matrix body members arranged adjacent to each other form a matrix body with a plurality of elongated cavities therein,

at least one of the matrix body members having matrix reinforcement components incorporated therein,

at least one of the elongated cavities being formed on an interface between matrix body members
and/or
at least two of the elongated cavities being formed transversely to each other and are formed so that each intersects an interface between matrix body members

reinforcing elements being arranged within the said cavities, and

the matrix body members and the reinforcing elements being interconnected by binder material having a composition different from that of the matrix body members to which they are interconnected.

52. A kit of parts as claimed in claim 50 or a reinforced structure as claimed in claim 51 which has any of the characteristics defined in any of claims 2 to 49.

Fig.1.

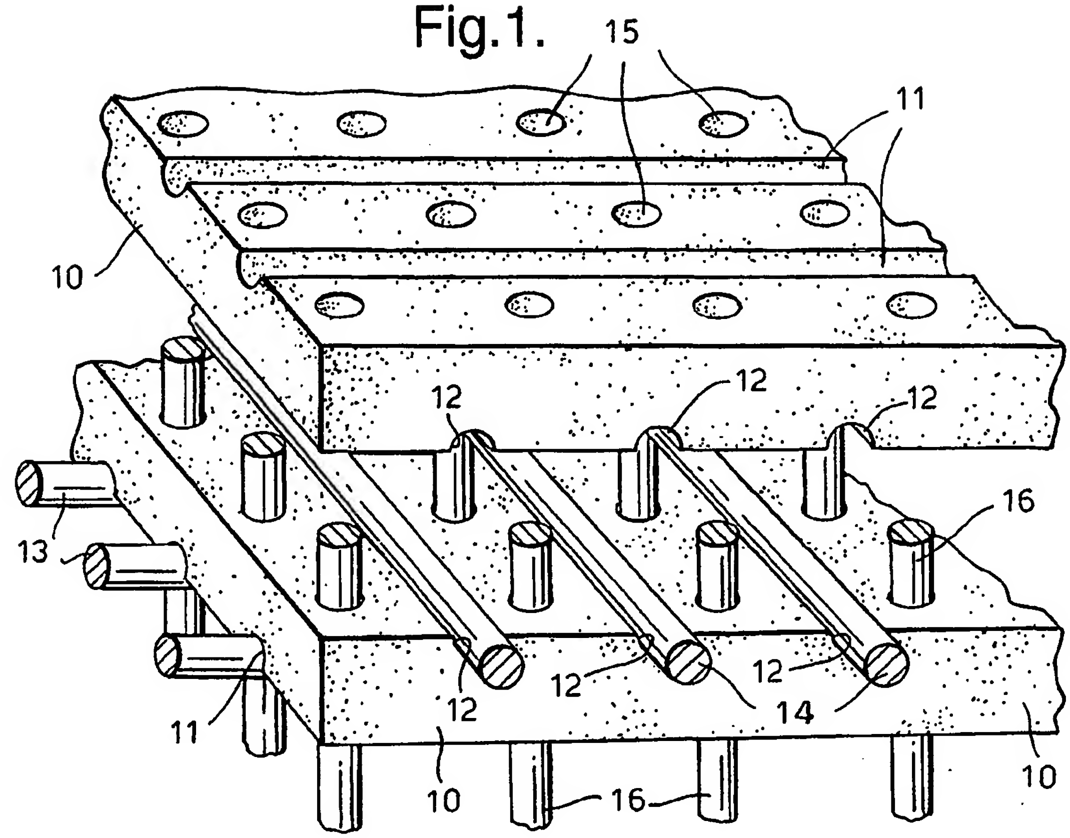
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Fig.2.

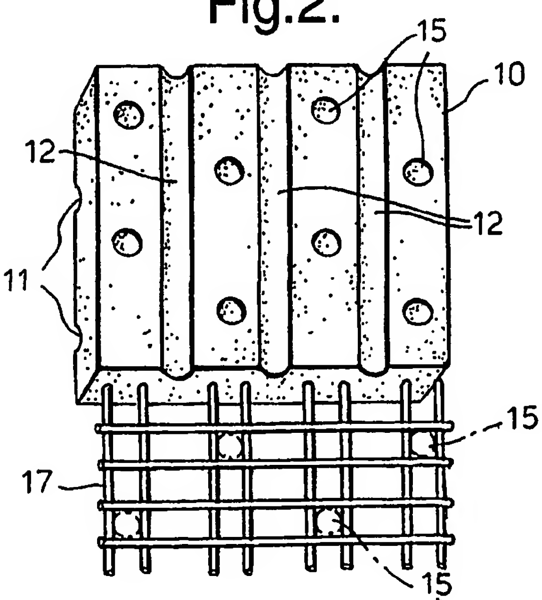
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Fig.3A.

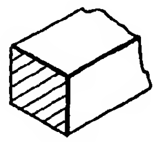


Fig.3B.

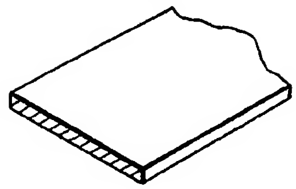


Fig.3C.

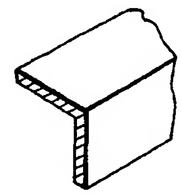


Fig.3D.

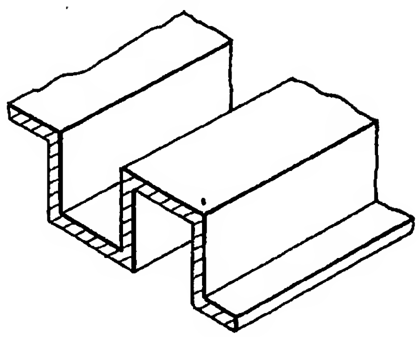


Fig.3E.

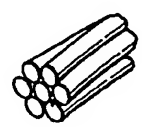


Fig.3F.

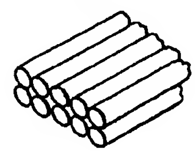


Fig.4A.

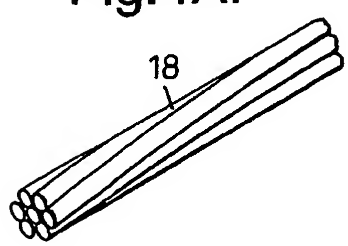


Fig.4B.

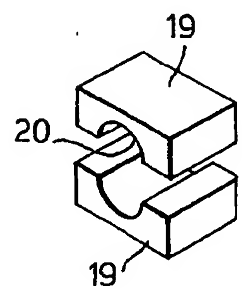


Fig.4C.

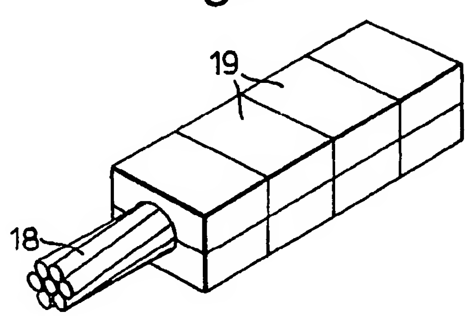


Fig.5A.

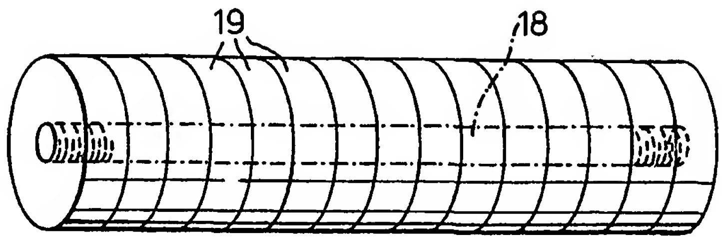


Fig.5B.

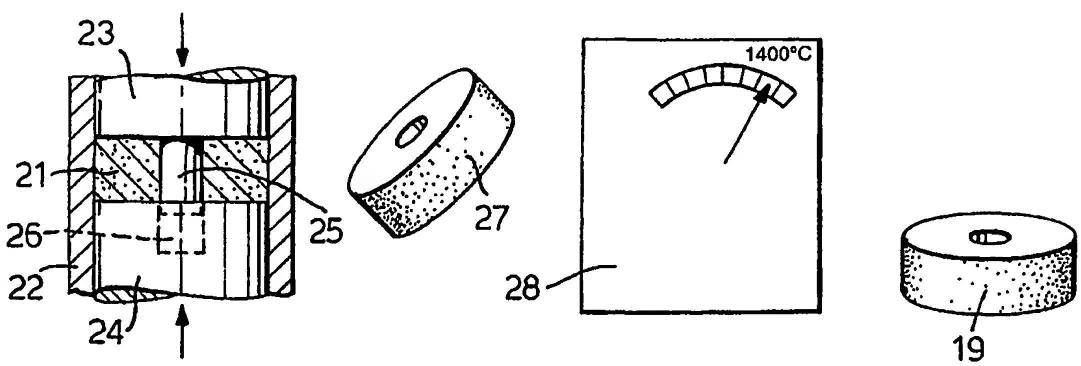


Fig.5C.

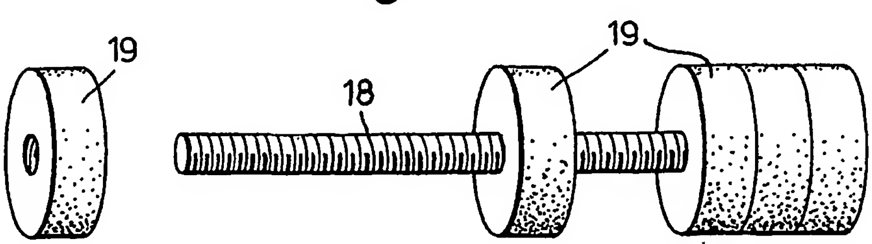


Fig.6.

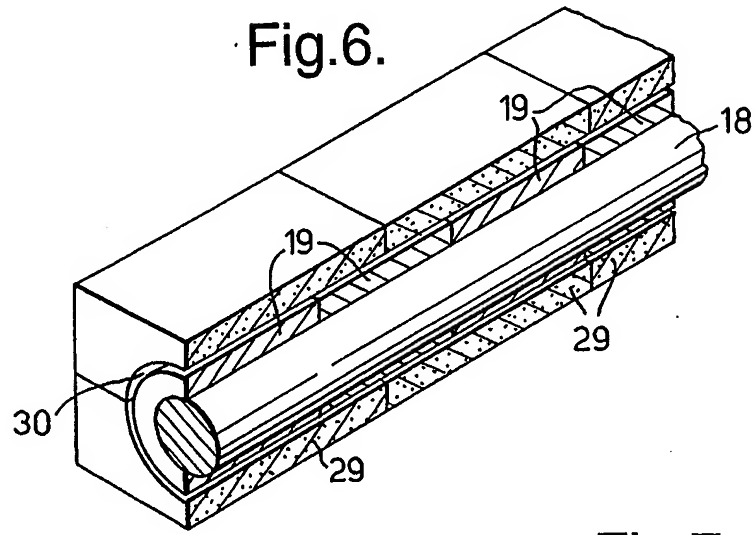


Fig.7.

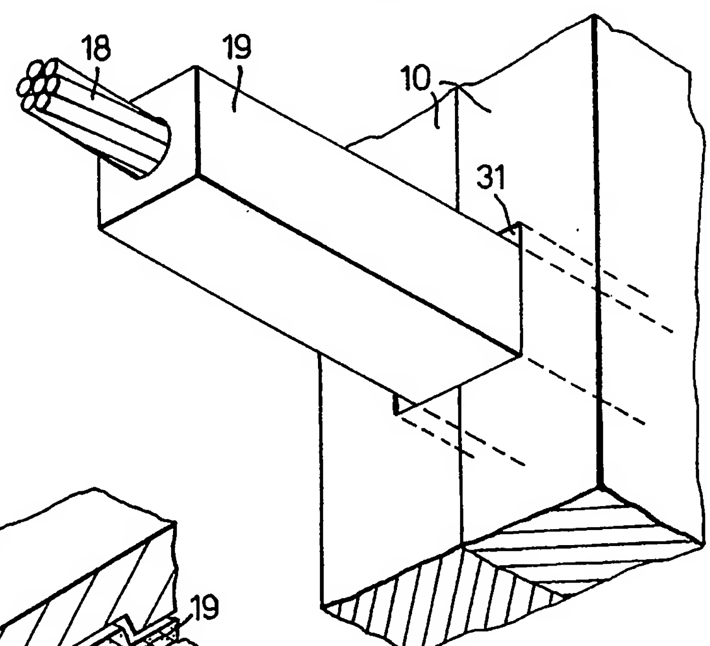


Fig.8.

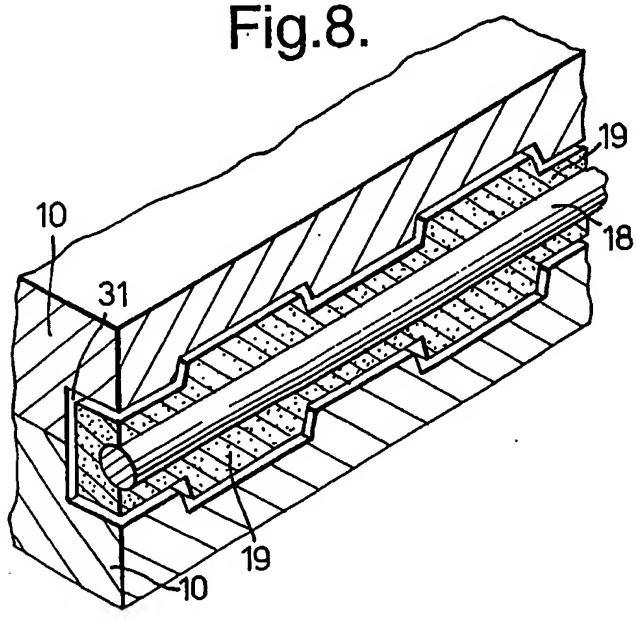


Fig.9.

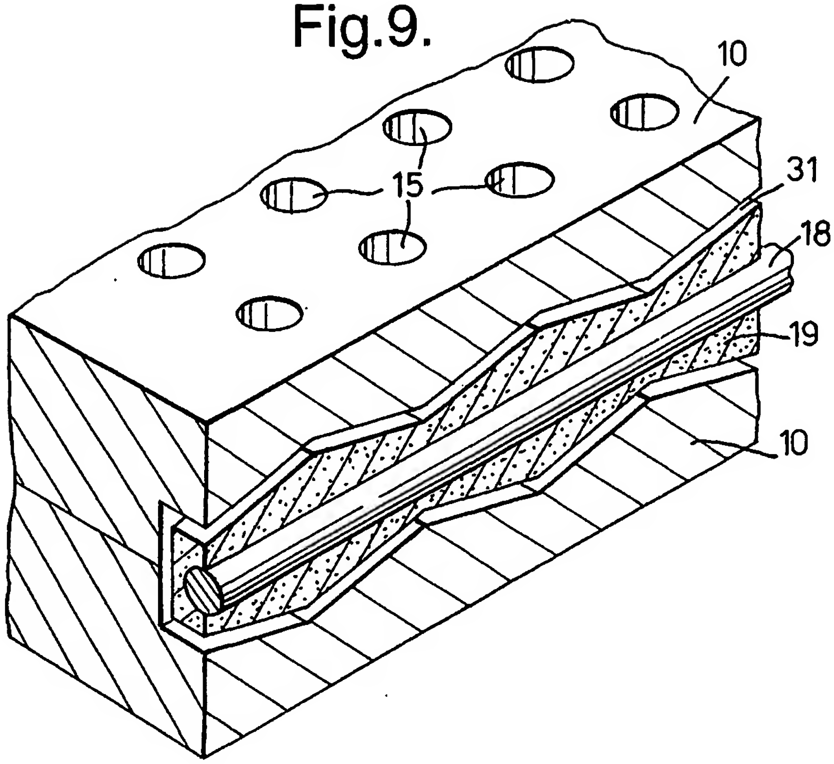


Fig.10.

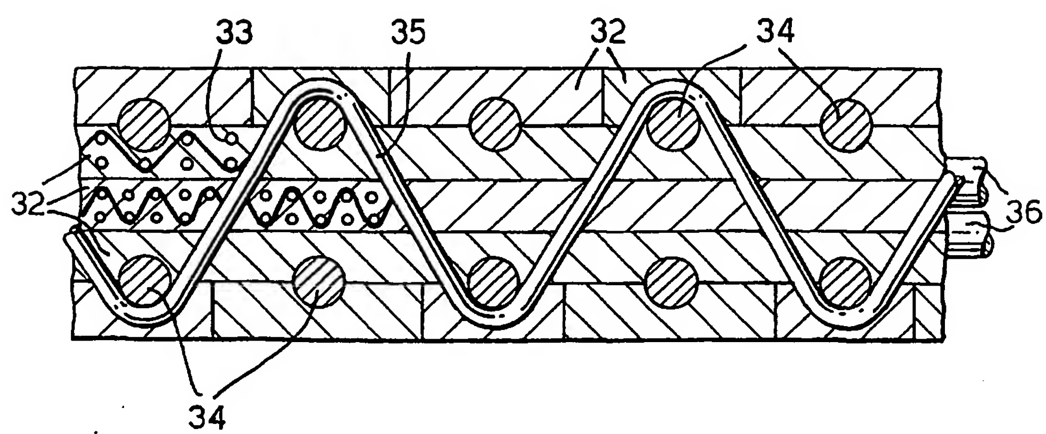


Fig.11.

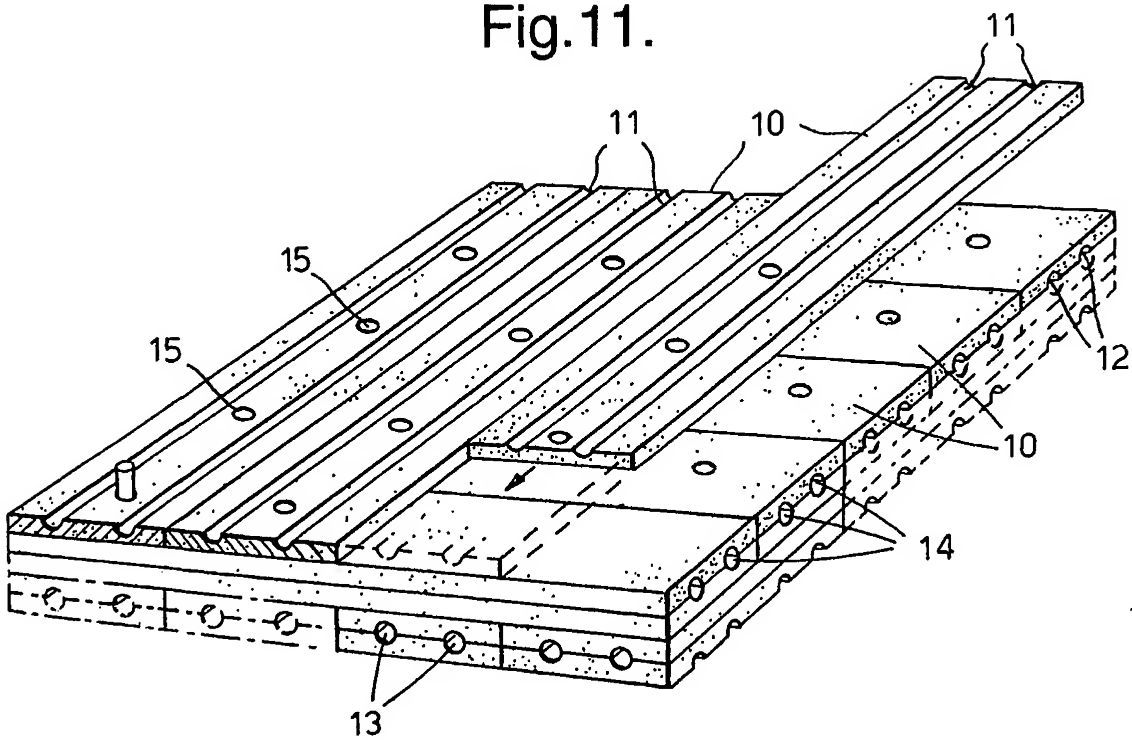


Fig.12.

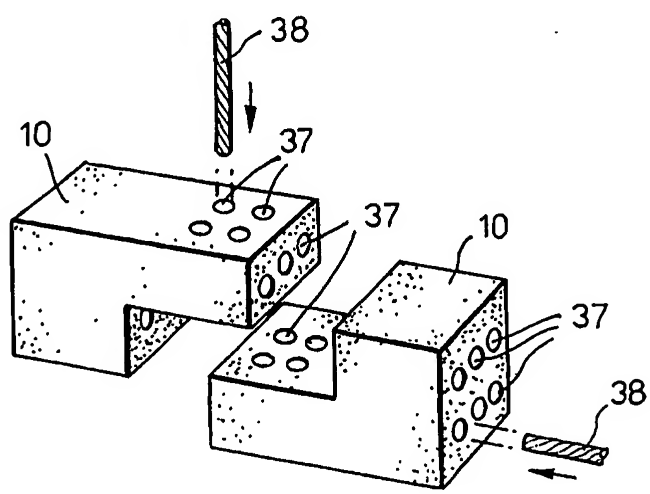


Fig.13A.

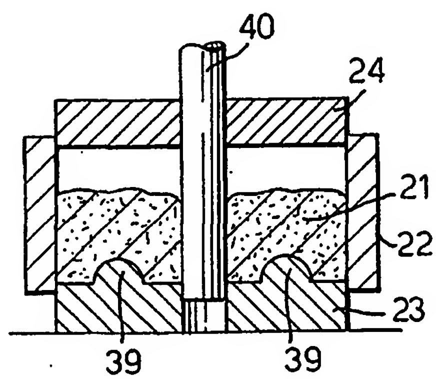


Fig.13B.

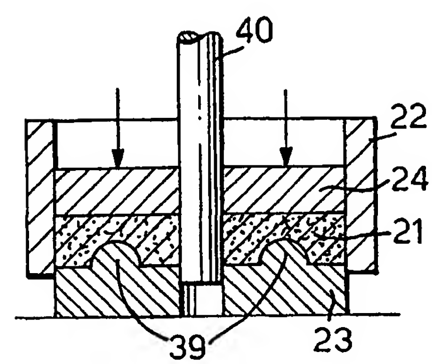


Fig.13C.

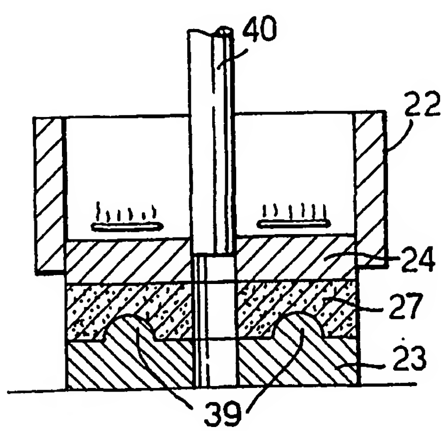


Fig.13D.

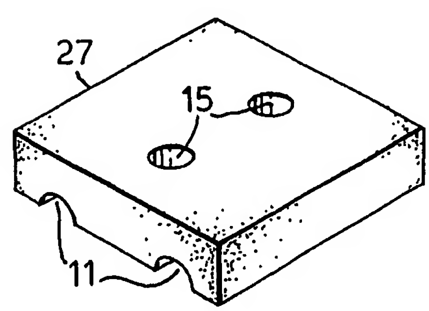


Fig. 16A.

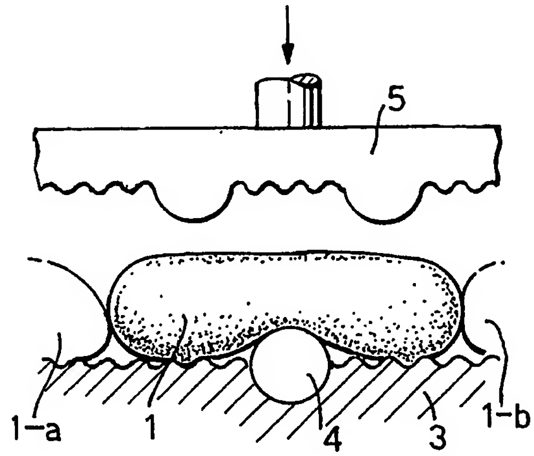


Fig. 16B.

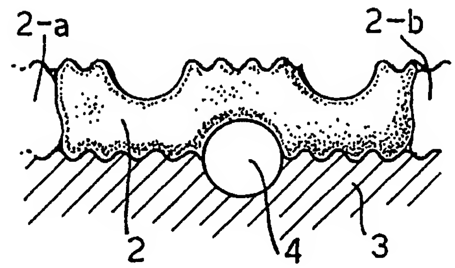


Fig. 17A.

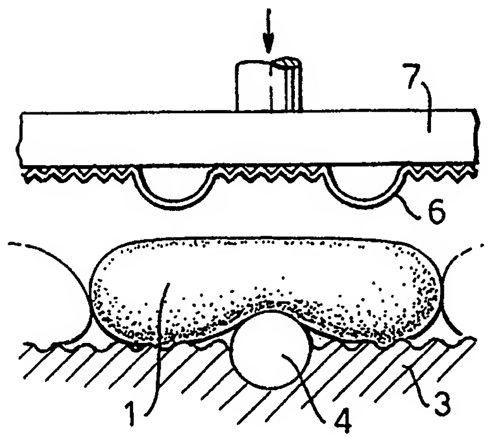


Fig. 17B.

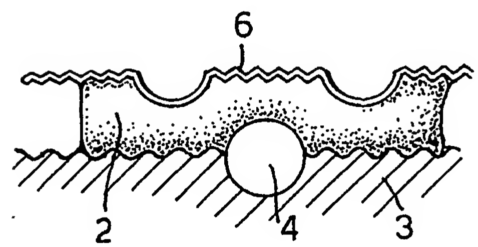


Fig. 18A.

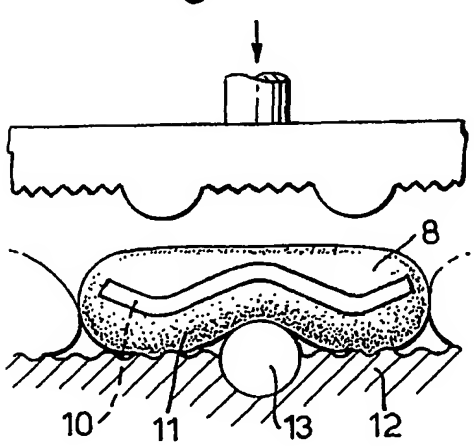


Fig. 18B.

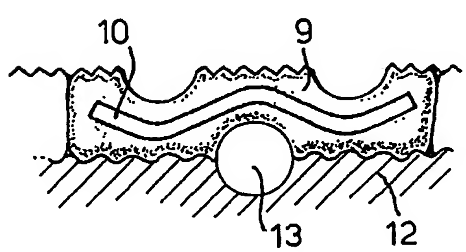
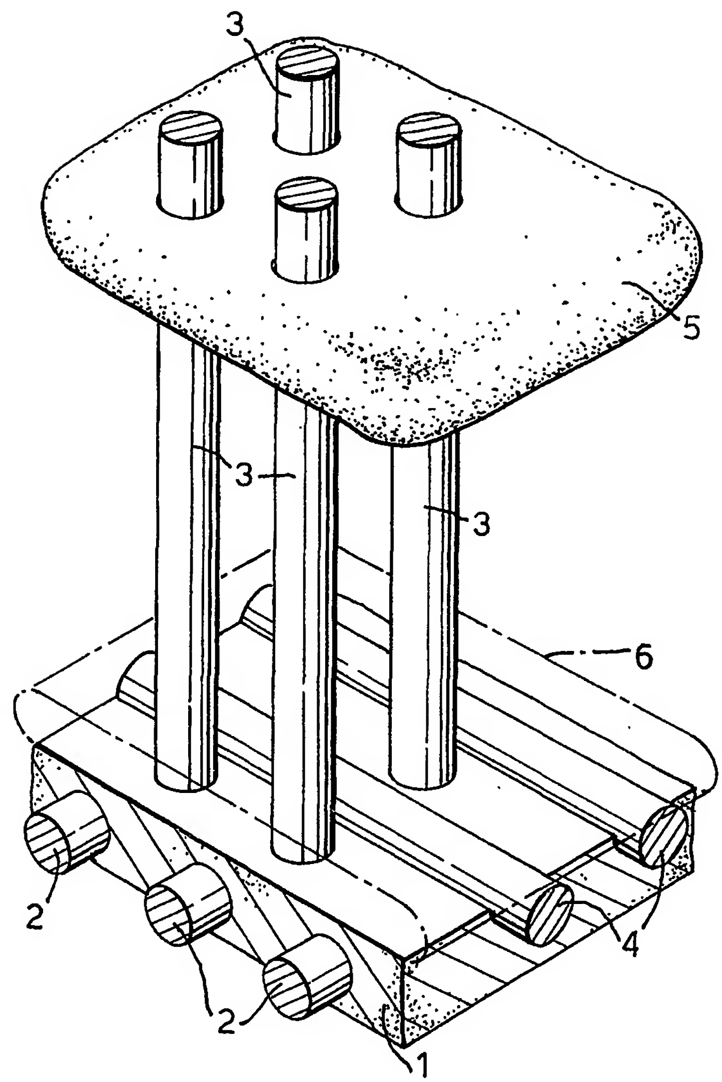


Fig.19.



INTERNATIONAL SEARCH REPORT

Intern al Application No
PCT/EP 01/04677

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E04C3/22 E04B5/08 E04H9/10 E01D19/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E04C E04B E04H E01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 1 085 852 A (MEYSEMBOURG) 8 February 1955 (1955-02-08)	1,2,4,6, 18-24, 34,35, 37-42, 47-52
Y	page 1, column 2, paragraph 2 -page 2, column 2, paragraph 5; figures	3,9-17, 25-33, 43-46
A		5,7,8,36

X	DE 89 11 453 U (BECKER) 23 May 1990 (1990-05-23)	1,2,4,6, 18-23, 34-41, 48-52
Y	page 14, line 1 -page 15, line 15; figures	5

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
5 September 2001	13/09/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Righetti, R

Intern al Application No
PCT/EP 01/04677

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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A	column 1, line 5 - line 50	1-6, 9-24,32, 41,42
	column 4, last paragraph -column 7, line 30; figures 3,7-16	
Y	US 4 979 992 A (BAHE) 25 December 1990 (1990-12-25) cited in the application	9-17,32, 33,44
A	column 3, last paragraph -column 4, paragraph 1 column 15, line 40 - line 50 column 23, line 34 - line 62; figures	1,6, 18-20
Y	US 4 588 443 A (BACHE) 13 May 1986 (1986-05-13) cited in the application	5
A	claims 1-29; figure 49	1,9-17, 36,44
A	US 2 106 177 A (HULTQUIST) 25 January 1938 (1938-01-25) the whole document	1-5
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A	FR 899 252 A (LACHAISE) 25 May 1945 (1945-05-25) figures	1

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Information on patent family members

International Application No
PCT/EP 01/04677

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